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(54) Microphone array with self-adjusting directivity for handsets and hands free kits

(57) The present invention proposes a transducer arrangement for a communication device, comprising an array of microphones (10) for receiving acoustic signals (11) from a sound source (12) and transducing received acoustic signals in electrical signals, and a processing means (13) for combining signals obtained from the microphones (10) of the array on the basis of differences in the signals related to the position of a sound source so that the directivity of the array of microphones is aligned towards the sound source.

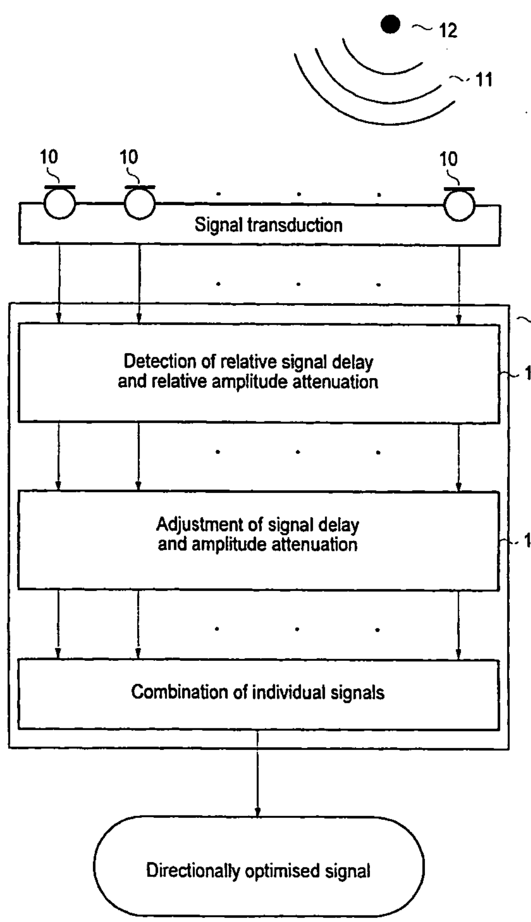

Figure 1

Description

[0001] The present invention relates to the field of communication devices, such as telephones for a wired or wireless communication system. Particularly, the present invention relates to a transducer arrangement for such a communication device, with an array of microphones e.g. for use in a car or an office or the like.

[0002] Microphones in nowadays telephones or hands free kits are typically of omnidirectional, unidirectional or bi-directional kind. In case of a directional microphone, the direction of the maximum sensitivity is defined by the overall construction of the microphone. The quality of the voice signal in this case is strongly dependent on the way the microphone is set in relation to a sound source.

[0003] Especially in hands free situations, the position of a sound source is not known and will most probably also vary in the course of time. In a car, for example, it might not always be the driver who answers the phone but very likely also one of the passengers will join in or several passengers may participate alternately in the telephone conversation. In this case a microphone with a fixed directivity, optimised for the person sitting on the driver's seat, will show a very reduced sensitivity for the other passengers in the car. Using a microphone with an omnidirectional characteristic in every direction is disadvantageous, since it also receives parasitic ambient noise, what results in a reduced speech quality.

[0004] US 4,521,908 proposes the use of a phased array of microphones instead of a single microphone. The array of microphones is set as a directional array, that means that the array is pre-set to a direction from which acoustic signals are expected.

[0005] It is therefore an object of the present invention to provide a microphone arrangement for a communication device with an optimal signal quality for non-stationary and/or alternating sound sources located at arbitrary positions.

[0006] This object is achieved by a transducer arrangement for a communication device, comprising an array of microphones for receiving acoustic signals from a sound source and transducing received acoustic signals in electrical signals, and a processing means for combining signals obtained from the microphones of the array on the basis of differences in the signals related to the position of a sound source so that the directivity of the array of microphones is aligned towards the sound source.

[0007] One of the main advantages of a microphone array with a self-adjusting directivity is, that the signal quality for a sound source anywhere within the reception area of the microphone array is optimised like for a conventional directional microphone, but additionally the sound source is free to move within the reception area, and for alternating sound sources no cutbacks in the signal quality have to be accepted. Further, the self-adjusting directivity advantageously guarantees that ambient noise will be suppressed independent of the position of the sound source. Therefore, while the driver of a car does not have to care on how to speak into the microphone for being heard clearly, he will be less distracted from the traffic situation. Also in conference situations with several people talking alternately to just one telephone device, the speech transmission quality will be improved greatly by the microphone arrangement automatically adjusting its directivity towards the currently talking person.

[0008] Advantageously, the processing means according to the present invention comprises a detecting means for detecting the differences in the delays of the signals from said array of microphones. Hereby, the detecting means advantageously further also detects differences in the amplitudes of the signals. In a particularly advantageously embodiment, the detecting means further detects the differences in the delays and/or the amplitudes of the signals on the basis of cross-correlation.

[0009] Advantageously, the processing means comprises an adjusting means for adjusting the differences in the delays of the signals from said array of microphones so that an optimised combined signal is obtained. Hereby, the adjusting means advantageously further adjusts for the differences in the signal amplitudes.

[0010] Further, advantageously the directivity of said array of microphones is realigned continuously during the reception of acoustic signals. This means that the directivity of the array of microphones will be automatically aligned to any sound source within its reach, even when the source of the sound moves rapidly and/or alternates.

[0011] Particularly advantageously, microphones with an omnidirectional characteristic are used in the array to allow a reception of acoustic signals from all directions.

[0012] An advantageous embodiment of the present invention uses an array of three microphones in a triangular arrangement placed e.g. on a sound reflecting surface like a table or the windscreen of a car, so that the directivity of the transducer arrangement can be steered in all spatial directions of the half space in front of this sound reflecting surface. In a further, particularly advantageously embodiment, four microphones in a tetrahedral array are used to achieve a good spatial resolution of the directional characteristic in all directions in space.

[0013] Further advantageously, the data obtained by the detecting means are used to adjust the directivity of a loudspeaker array towards the origin of the sound source to improve the acoustic irradiation of a talking person.

[0014] The transducer arrangement according to the present invention can e.g. be implemented in a communication device such as a mobile cellular radiophone for an improved speech quality independent of the way a user holds his phone, or as a part of a hands free kit for

use in an automobile so that neither the driver nor the passengers of a car have to care for the direction in which to speak. Another implementation of the transducer arrangement according to the present invention is in a wired telephone for hands free situations and in conference telephones as an adaptive directional transducer.

[0015] The present invention will be described in further detail with reference to the accompanying drawings, in which

Figure 1 shows a block diagram of a microphone arrangement according to the present invention, and

Figure 2 shows a first preferred microphone array, and

Figure 3 shows a second preferred microphone array, and

Figure 4 compares the directional sensitivity of an omnidirectional microphone with the directional sensitivity of the microphone arrangement according to the present invention as obtained for a sound source located at two exemplary positions.

[0016] Fig. 1 shows the block diagram of a microphone arrangement, which comprises an array of microphones 10 and a processing means 13 for controlling the directional characteristic of the array. It is to be understood that in Fig. 1 only elements important for the understanding of the present invention are shown. The array of spaced apart microphones 10 transduces the acoustic signal of a sound source in a plurality of individual electrical signals, which differ from each other according to their position relative to the source of the sound 12. Depending on the situation for which the transducer arrangement is used, the individual microphones may be located at predefined favoured positions within a part of the communication device. For example in cellular radiophones this will be at locations which will not be covered by the hand or the ear of the user, and in the case of a conference telephone the array of microphones will be mounted in the microphone/loudspeaker unit. In other situations like e.g. in hands free kits for use in cars, the microphones may be placed individually at strategic locations like e.g. the windscreen and/or one of the other window panes of the car. But also the rear view mirror, the dashboard or the trim panels are suited places. For special situations, like e.g. for distributed communication devices such as videotelephones mounted in a car or also in stretch-limousines, the seats, the roof, or other parts of the interior equipment may be used as a mounting support for the microphones.

[0017] In the processing means 13, the signals 11 from the individual microphones 10 of the array are processed to a combined signal such, that the direction of the maximum sensitivity of the array is directed towards the main sound source 12. This processing means can be integrated in a communication device or can be realised externally, like e.g. within a hands free kit or as a part of an audio system of a car being connected to the communication device.

[0018] The further processing and transmission of the directionally optimised combined signal is done by the communication device employing the conventional methods for modulation and transmission of an audio signal.

[0019] The differences in the delays of the signals from the microphones are detected in the detecting means 14 of the processing means 13. Alternatively hereto, the differences in the signal amplitudes are detected additionally. Hereby the cross-correlation method can be used for detecting the respective characteristic differences.

[0020] The individual signals are adjusted in the adjusting means 15 with respect to the detected characteristic signal differences such, that when the adjusted signals are combined to one, the part of the signal originating from the direction of the main sound source is emphasised, and the other parts of the signal originating from positions off that direction are attenuated.

[0021] In a preferred embodiment of the present invention as shown in Fig. 2, the microphone array is setup of three omnidirectional microphones 10 placed at different points of an arbitrarily shaped boundary surface 20 thereby forming the corners of a triangle. The distance between two adjacent microphones of the array thereby is preferably smaller than a half of the shortest wavelength processed. Any sound signal 11 produced within the volume given by the reach of each of the microphones will be captured. With the boundary surface comprising a sound reflecting characteristic, the microphone array will cover the half space in front of the boundary surface.

[0022] The distances (d1, d2, d3 in Fig.2) between each of the microphones of the array and the sound source vary with the position of the sound source. Associated with said distances are time delays between the generation and the reception of a sound signal. With the microphones being spaced apart, differences in the distance to the sound source 12 for each of the microphones 10 become a function of the orientation of the sound source 12 relative to the microphone array. The differences in distance result in different travelling times of the sound wave from its source to each of the microphones, thereby causing relative time delays between equal signals at different microphones. These time delays can be treated as phase shifts between the signals, with the values of phase shifts being an indicator for the relative position of the sound source.

[0023] Further, different distances between the sound source and the individual microphones will result in dif-

ferent amplitudes of the received signals. If a microphones directional characteristic deviates from that of an ideal omnidirectional sensitivity, the signal amplitude will further vary with the reception angle.

[0024] With the wanted signal assumed to be considerably more intense than the noise at all frequencies, the differences in the delays as well as in the amplitudes of the signals as they are obtained from the different microphones can be determined. Advantageously, the relative signal phase shifts corresponding to the individual signal delays and the characteristic differences in the signal amplitudes are hereby calculated by cross-correlating the signals, showing maxima at the respective characteristic features.

[0025] Next, the gain factor for the amplification of the individual signals is adjusted to compensate for the different signal intensities at the individual microphones due to a varying angular sensitivity of the single transducers and their different distance to the sound source as well as to achieve a desired directivity of the microphone array. This is followed by adding a time delay to each of the signals such, that the resulting phase shifts between the individual signals become zero in respect to the desired signal. The final additive superposition of the individual signals, which were modified in gain and phase shift as described above, constricts the angular sensitivity 40 of the microphone array compared to that of the individual microphones and increases the overall gain, thus generating a main lobe which is steered towards the direction of the main sound source, like illustrated in Fig. 4.

[0026] The time necessary for processing the signals in the above described manner is short compared to the reaction time of a human hearing. In relation to the human perception, the autotracking of the arrays directivity towards the main sound source therefore appears to be done instantly. A constant control and processing of the received signals thereby ensures an optimal signal quality even under the condition of moving sound sources and/or sources of alternating position in environments with high ambient noise.

[0027] For the arrangement described above, the best results are obtained in the semi-space in front of the microphone array. With the sound source being located in an arbitrary direction of the full space around the microphone array, at least four microphones have to be placed in a non planar arrangement. Putting at least four microphones at the comers of a spatial geometrical body with the length of the body's edges smaller than a half of the shortest processable wavelength will result in an excellent signal quality for sound sources located at arbitrary positions and emitting in different directions.

[0028] The area of reception thereby is not restricted to the space formed by the geometrical arrangement of the microphones but by the direction in which a sound source emits. Consequently, the arrangement of the microphones is to be set that within the desired reception volume a sound being emitted from any source in any valid direction has to be received by at least one of the individual microphones. With the number of microphones used in an array, the signal processing time will also increase. With the array shown in Fig. 3, where four omnidirectional microphones are placed at the comers of a tetrahedron, all directions in space are covered for the reception of a sound signal from a volume much larger than the volume put up by the microphones, and the signal processing time is short enough, so that for the human perception the autotracking of the arrays directivity will occur immediately.

[0029] In a further advantageous embodiment of the present invention, the parameters used to adjust the directivity of the microphone array towards the sound source are further used for directing the radiating direction of a loudspeaker array towards the origin of that sound source. The array of loudspeaker does not necessary have to be arranged near or close to the microphone array. The directivity parameters as determined by the detecting means 14 in relation to the position of the microphone array are thereby converted in the directivity parameters for the loudspeaker array by the processing means 13. This way, the conversating partners can hear each other quite clearly.

Claims

1. Transducer arrangement for a communication device, comprising

   an array of microphones (10) for receiving acoustic signals (11) from a sound source (12) and transducing received acoustic signals in electrical signals, and
   a processing means (13) for combining signals obtained from the microphones (10) of the array on the basis of differences in the signals related to the position of a sound source so that the directivity of the array of microphones is aligned towards the sound source.

2. Transducer arrangement for a communication device according to claim 1,
   characterised in
   that the processing means (13) comprise a detecting means (14) for detecting the differences in the delays of the signals from said array of microphones.

3. Transducer arrangement for a communication device according to claim 2,
   characterised in
   that said detecting means (14) further detects differences in the signal amplitudes of the signals from said array of microphones.

4. Transducer arrangement for a communication device according to claim 2 or 3, **characterised in** **that** said detecting means (14) further detects differences in the delays and/or the signal amplitudes of the signals from said array of microphones on the basis of cross-correlation.

5. Transducer arrangement for a communication device according to one of the claims 2 to 4, **characterised in** **that** the processing means (13) comprise an adjusting means (15) for adjusting the differences in the delays of the signals from said array of microphones so that an optimised combined signal is obtained.

6. Transducer arrangement for a communication device according to claim 5, **characterised in** **that** said adjusting means (15) further adjusts the differences in the signal amplitudes of the signals from said array of microphones.

7. Transducer arrangement for a communication device according to one of the claims 1 to 6, **characterised in** **that** the directivity of said array of microphones is realigned continuously during the reception of acoustic signals.

8. Transducer arrangement for a communication device according to one of the claims 1 to 7, **characterised in** **that** said microphones have an omnidirectional characteristic (40).

9. Transducer arrangement for a communication device according to one of the claims 1 to 8, **characterised in** **that** said array of microphones is made up of three microphones arranged to form a triangle (20).

10. Transducer arrangement for a communication device according to one of the claims 1 to 8, **characterised in** **that** said array of microphones is made up of four microphones arranged at the corners of a tetrahedron (30).

11. Transducer arrangement for a communication device according to one of the claims 1 to 10, **characterised in** **that** the data obtained by said detecting means are used to adjust the directivity of a loudspeaker array.

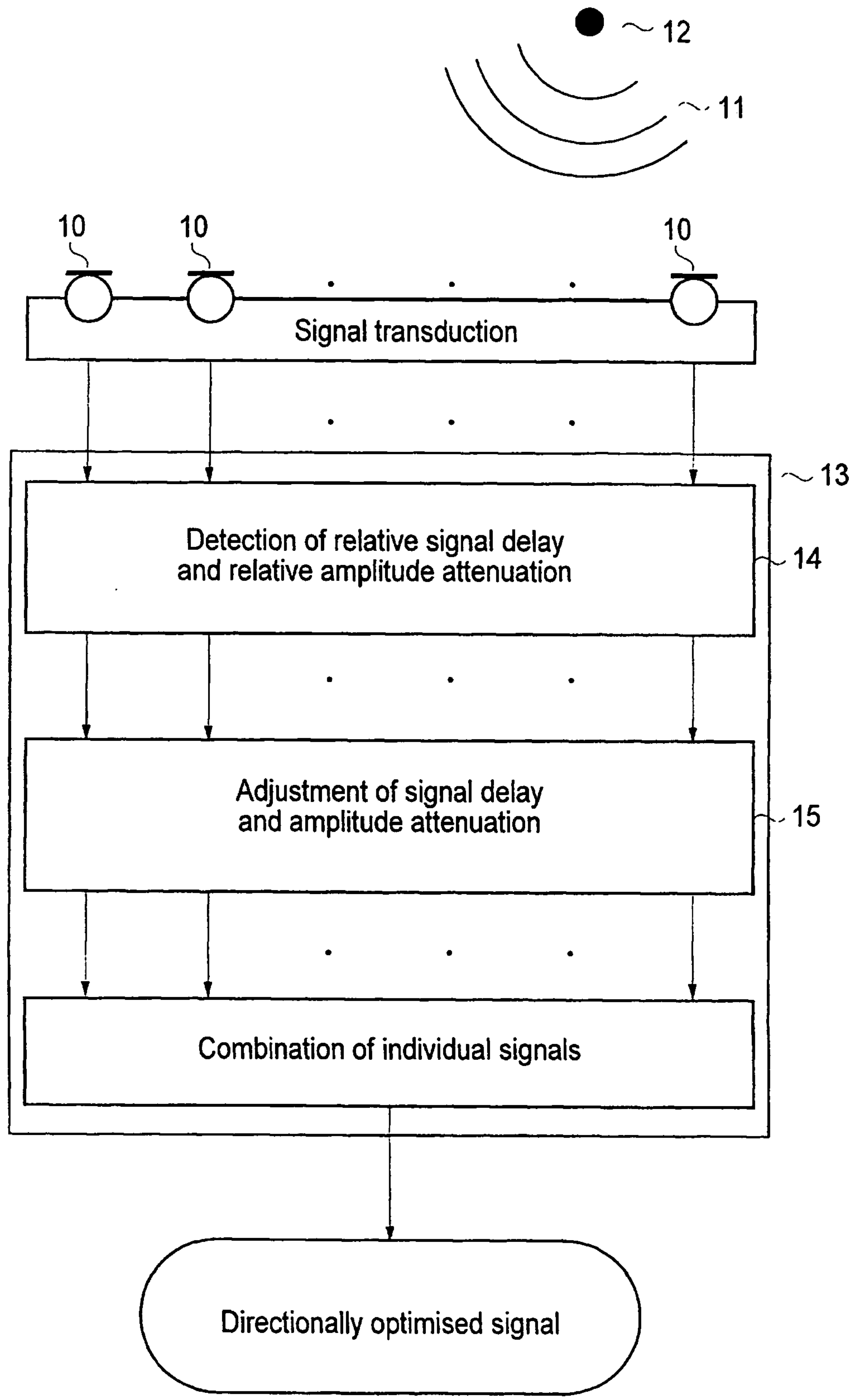
12
11
10
10
10
Signal transduction
13
Detection of relative signal delay
and relative amplitude attenuation
14
Adjustment of signal delay
and amplitude attenuation
15
Combination of individual signals
Directionally optimised signal

Figure 1

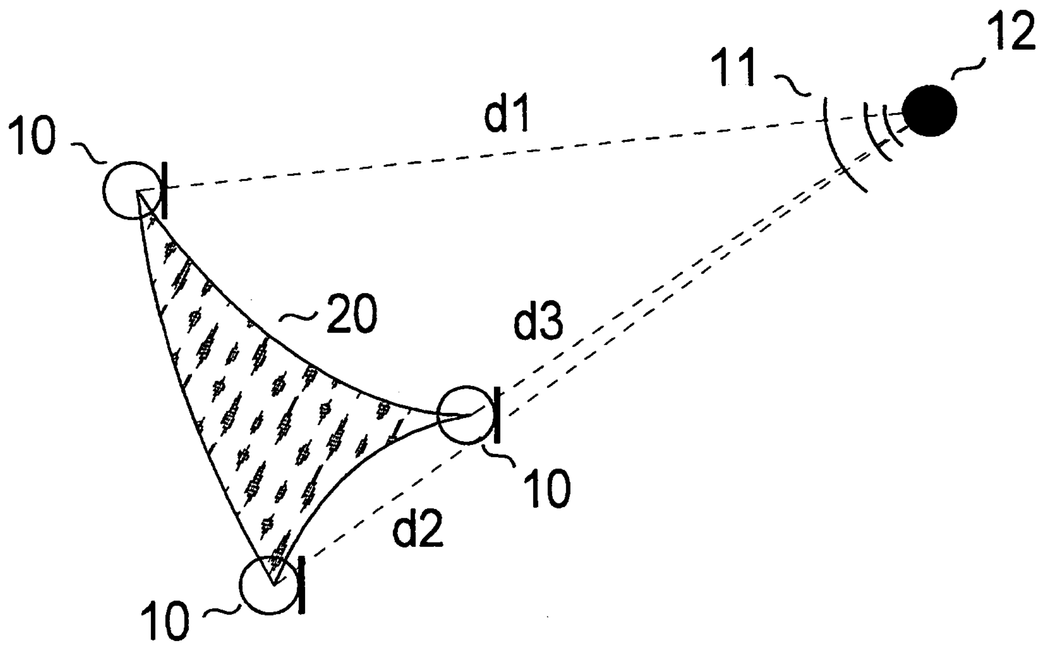

Figure 2

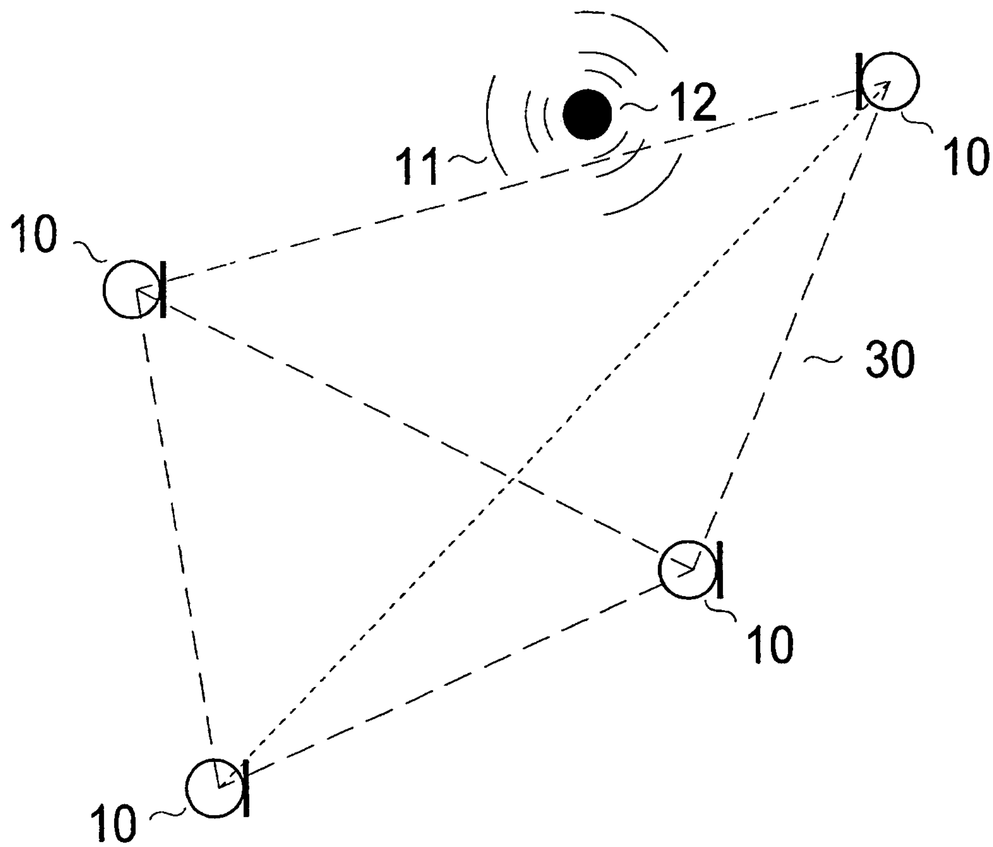

Figure 3

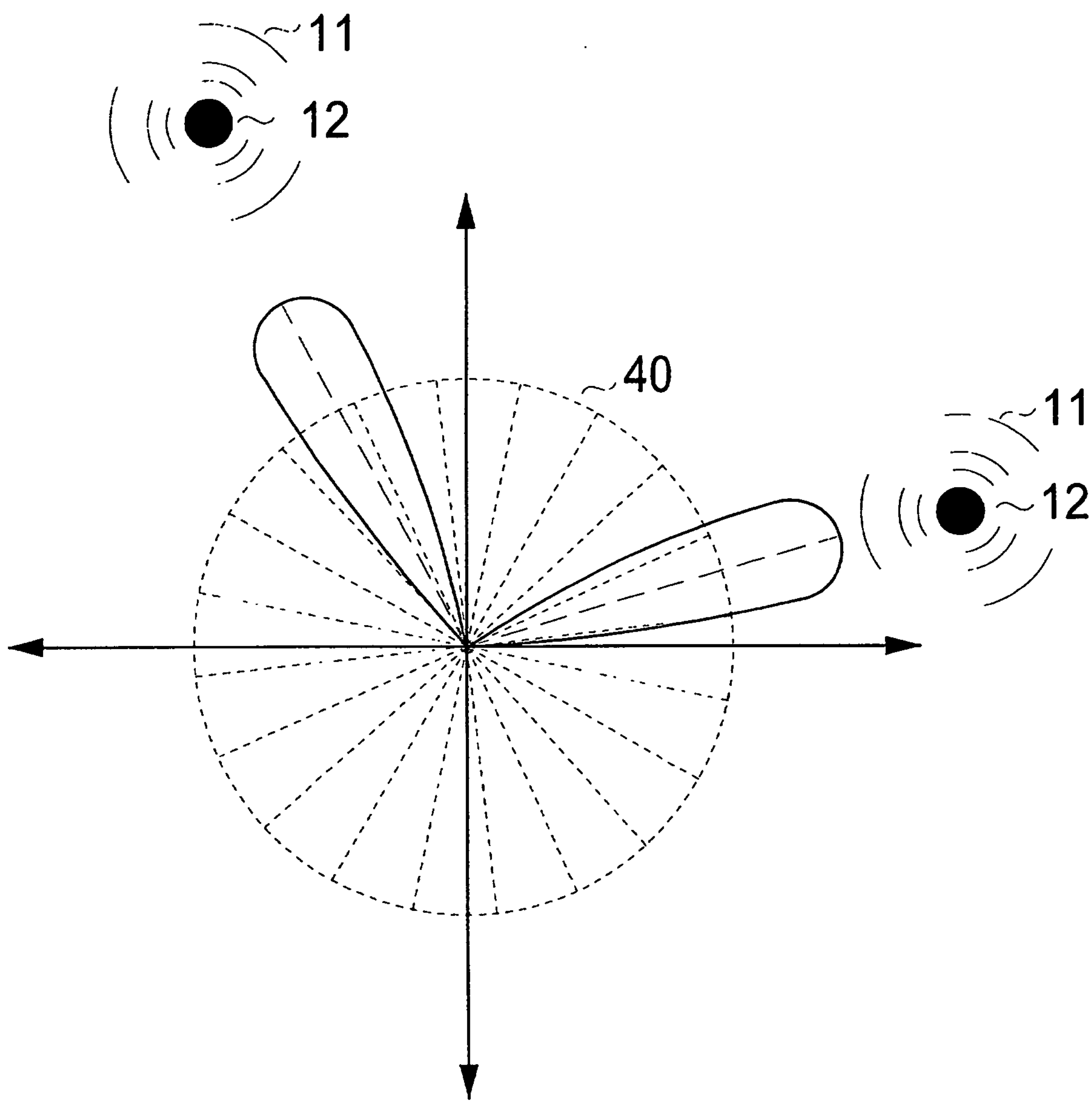

Figure 4

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EUROPEAN SEARCH REPORT

Application Number
EP 00 12 4648

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TECHNICAL FIELDS SEARCHED (Int.Cl.7)
H04R

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	31 July 2001	Nieuwenhuis, P

CATEGORY OF CITED DOCUMENTS

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EUROPEAN SEARCH REPORT

Application Number
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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	31 July 2001	Nieuwenhuis, P

CATEGORY OF CITED DOCUMENTS

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